STROBE LIGHT TESTING AND KOKANEE POPULATION MONITORING DWORSHAK DAM IMPACTS ASSESSMENT AND FISHERIES INVESTIGATION PROJECT, 87-99

Period Covered: January - December 1997

Annual Progress Report

DOE/BP-35167-8

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views of this report are the author's and do not necessarily represent the views of BPA.

This document should be cited as follows:

Maiolie, Melo A., Bill Harryman, Bill Ament - Idaho Department of Fish and Game, Strobe Light Testing and Kokanee Population Monitoring, Dworshak Dam Impacts Assessment And Fisheries Investigation Project, 87-99, Annual Progress Report Period Covered: January - December 1997, Report to Bonneville Power Administration, Contract No. 1987BP35167, Project No 198709900., 26 electronic pages (BPA Report DOE/BP-35167-8)

This report and other BPA Fish and Wildlife Publications are available on the Internet at:

http://www.efw.bpa.gov/cgi-bin/efw/FW/publications.cgi

For other information on electronic documents or other printed media, contact or write to:

Bonneville Power Administration
Environment, Fish and Wildlife Division
P.O. Box 3621
905 N.E. 11th Avenue
Portland, OR 97208-3621

Please include title, author, and DOE/BP number in the request.

FISHERY RESEARCH

Strobe Light Testing
and
Kokanee Population Monitoring

DWORSHAK DAM IMPACTS ASSESSMENT AND FISHERIES INVESTIGATION PROJECT, 87-99

Annual Progress Report
Period Covered: January - December 1997
Contract Number 87BP35167

By:
Melo A. Maiolie, Principal Fisheries Research Biologist
Bill Harryman, Senior Fisheries Technician
Bill Ament, Senior Fisheries Technician
Idaho Department of Fish and Game
600 S. Walnut St. Box 25, Boise ID 83707

Prepared for:
Bonneville Power Administration
P.O. Box 3621, Portland, Oregon 97208
November 1999
IDFG 00-09

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

We tested the response of kokanee *Oncorhynchus nerka* to strobe lights. Testing was conducted on wild, free-ranging fish in their natural environment (i.e., the pelagic region of two large Idaho lakes). Split-beam hydroacoustics were used to record the distance kokanee moved away from the lights, as well as the density of kokanee in the area near the lights. In control tests, where strobe lights were lowered into the lake but kept turned off, kokanee remained within a few meters of the lights. Once the lights began flashing, kokanee quickly moved away from the light source. Kokanee moved 20 to 40 m away from the lights in waters with Secchi transparencies from 3 to 5 m. Kokanee densities near the lights were significantly lower (p=0.07 to p=0.00) when the lights were turned on than in control samples with no lights flashing. Flash rates of 300, 360, and 450 flashes/min elicited strong avoidance responses from the fish. Kokanee remained at least 24 m from the lights during our longest test that lasted for 5 h 50 min.

We also continued annual monitoring of the kokanee population in Dworshak Reservoir. Spawner counts in four tributary streams that were used as an index of the adult population reached a record low of 144 spawners. No age-1 or age-2 kokanee were caught in 15 trawl hauls used to make population estimates. The population estimate of fry was 65,000 fish, +/- 76% (90% C.I.). Flooding during the spring of 1996 was responsible for the low kokanee population.

Authors:

Melo A. Maiolie
Principal Fishery Research Biologist

Bill Harryman
Senior Fisheries Technician

Bill Ament
Senior Fisheries Technician

INTRODUCTION

During 1996, kokanee *Oncorhynchus nerka* in Dworshak Reservoir suffered major declines when large amounts of water were released through the dam (Maiolie et al. 1998). All year classes of kokanee were reduced to the lowest levels documented in recent history. This year, 1997, we began testing strobe lights with the hope of limiting entrainment losses in the future. Testing was conducted off-site in Spirit Lake and Lake Pend Oreille where kokanee densities were higher. We also monitored the kokanee population by mid-water trawling and spawner counts to see if any natural recovery of the population occurred.

OBJECTIVE

To maintain densities of 30 to 50 adult (age-2 and older) kokanee/ha in Dworshak Reservoir by reducing entrainment losses.

DESCRIPTION OF STUDY AREA

Dworshak Dam is located on the North Fork of the Clearwater River in northern Idaho. At 219 m tall, it is the largest straight-axis concrete dam in the United States. It was built in 1971 for power production and flood control. Three turbines within the dam have a total operating capacity of 450 megawatts. The dam can discharge up to 380 m^3/s (10,000 cfs) through the turbines and another 420 m^3/s (15,000 cfs) through reservoir outlets and the spillway.

The reservoir behind the dam is 86 km long at full pool (Figure 1). Maximum and mean depths are 194 m and 56 m, respectively. Surface area at full pool is 6,644 ha with 5,400 ha of kokanee habitat (defined as the area over 15 m deep). Drawdowns for flood control may lower the surface elevation 47 m and reduce surface area by as much as 52%. The reservoir has a mean retention time of 10.2 months and a mean annual discharge of 162 m^3/s (Falter 1982). High releases from the reservoir occur during spring runoff, during the fall when the reservoir is lowered for flood control, during late summer when water is released for anadromous fish flows, and during storm events.

Kokanee were first stocked into Dworshak Reservoir in 1972 (Horton 1981). Four sources of fish were initially used, but the early spawning strain from Anderson Ranch Reservoir, Idaho now populates the reservoir (Winans et al. 1996). These fish spawned during September in tributary streams as far as 140 km above the reservoir. They reached maturity primarily at age-2, although age-1 and age-3 spawners were occasionally found. Adults ranged in size from 200 to 400 mm in total length depending on density in the reservoir, but generally averaged 300 mm during spawning (Maiolie and Elam 1995).

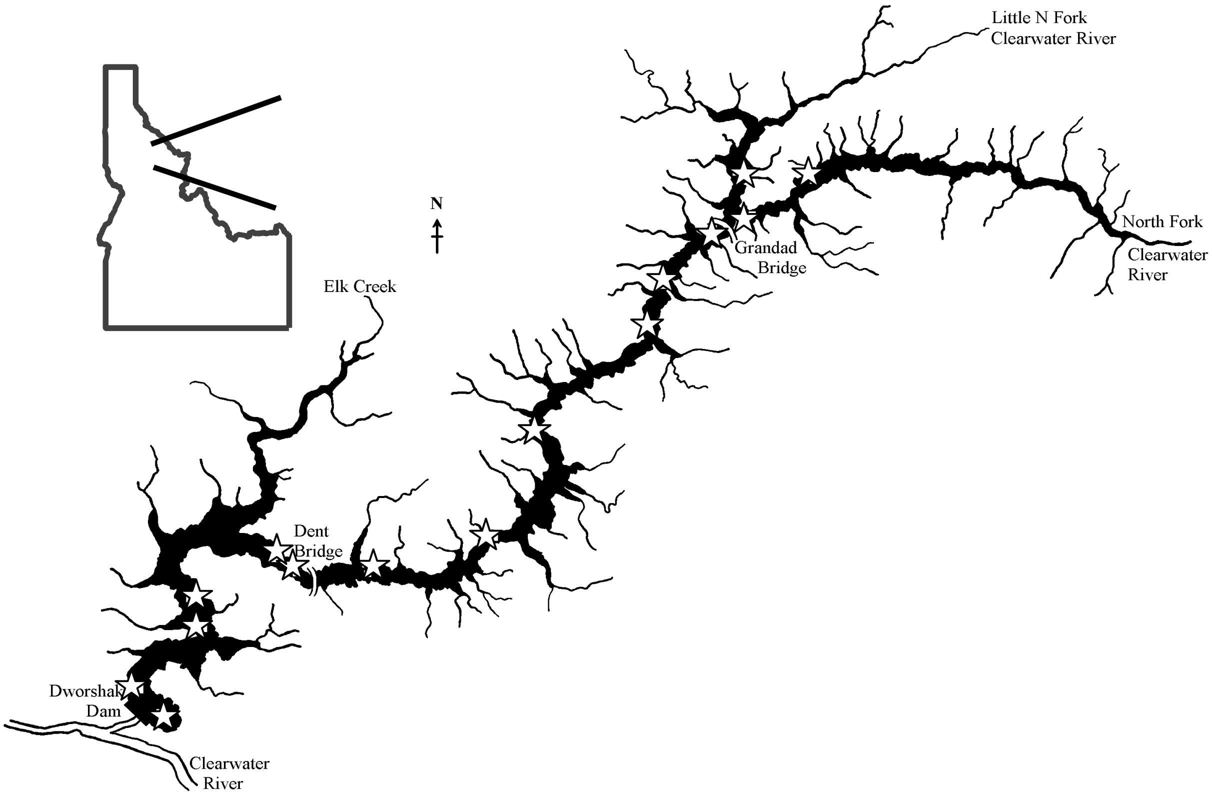


Figure 1. Map of Dworshak Reservoir and its major tributaries, North Fork Clearwater River, Idaho. Stars indicate random locations where midwater trawling was conducted in 1997.

Spirit Lake is located in the northern panhandle of Idaho near the town of Spirit Lake. It is approximately 526 ha and contains a strong population of kokanee of nearly 1,000 fish/ha (based on trawling).

Lake Pend Oreille is also located in the northern panhandle of Idaho between the towns of Sandpoint and Bayview. This lake is about 38,000 ha with a maximum depth of 350 m. Kokanee densities based on trawling were approximately 200 fish/ha; however, concentrations of kokanee were found where densities exceeded 1,000 fish/ha. Areas with higher densities were used during our testing.

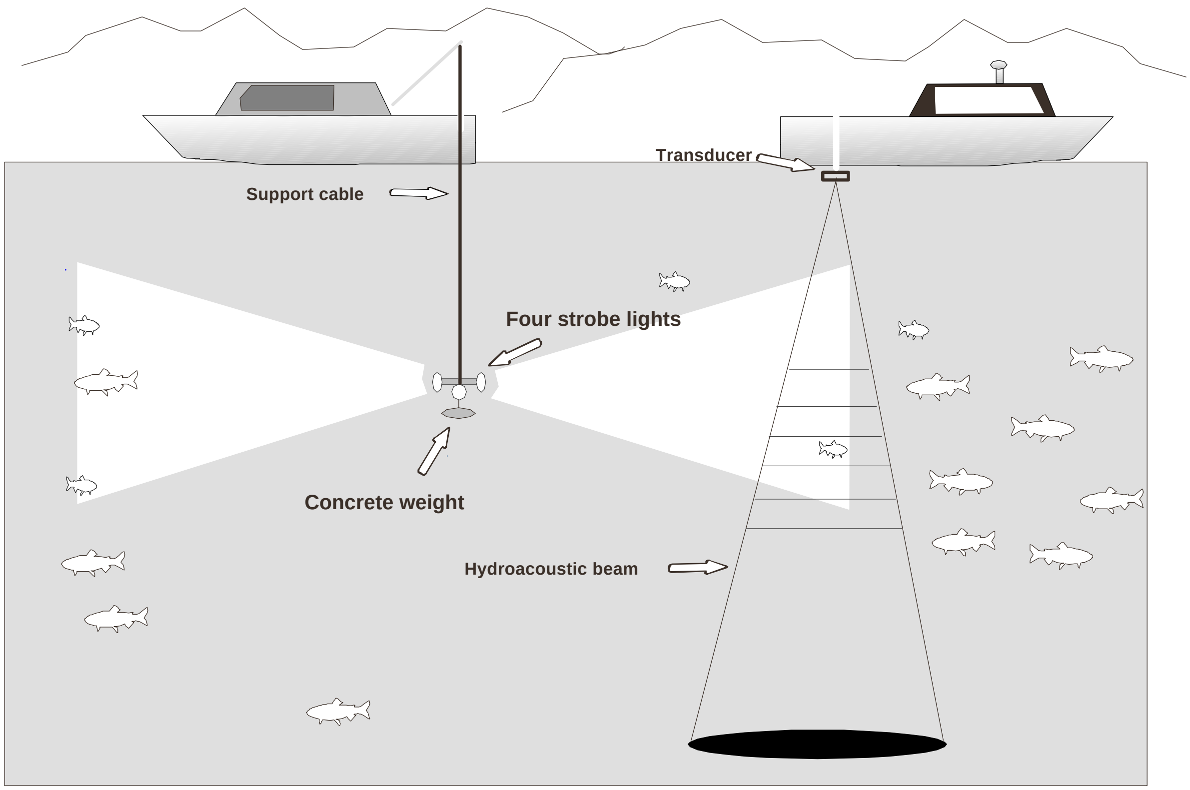


Figure 2. Arrangement of boats in the strobe light tests. One boat raised and lowered the the lights while a second boat conducted hydroacoustic surveys

METHODS

Strobe Light Tests

Strobe lights used in these experiments were built by Flash Technologies, Franklin, TN. Four flash heads were supported in the water by a vertical steel cable with the lights pointed horizontally at 90^o angles. We could not synchronize the flash heads so that they flashed at the same time. A concrete weight held the lights down (Figure 2). Power was supplied by a 5,000-watt portable gas powered generator. During testing, we set the strobe lights to flash at rates of 300, 360, or 450 flashes/min.

One boat, equipped with hydraulic winches, raised and lowered the lights. This boat either was allowed to drift or was anchored during testing. A second boat was equipped with hydroacoustic gear. This boat conducted surveys past the first boat to determine the distribution of kokanee near the lights, and to estimate fish densities in the area of the lights (Figure 2). We used a Simrad EY500 split-beam scientific echosounder with a 120 kHz transducer to document the response of kokanee to our strobe lights. Boat speed was 1 to1.5 m/s and all surveys were conducted at night. The echosounder was set to ping at 0.5 to 1.0 s intervals, depending on water depth, with a pulse width of 0.3 milliseconds. Data were collected with a time varied gain constant of 20 log r (range). We calibrated the echosounder at the beginning of the year using a 23-mm copper calibration sphere with a target strength of -40.4 dB (decibels) (at 23^{o}C). We checked the calibration of the echosounder prior to each test and adjusted the transducer gains if needed. Fish density estimates were calculated using EP-500 software, version 4.5. Densities were based on echo integration techniques to account for fish within schools that could not be distinguished as single targets. Tests were conducted on either Spirit Lake or Lake Pend Oreille. We felt confident that nearly all pelagic fish in these lakes were kokanee, based on mid-water trawling at night from 1987 to 1994. Trawl catch was composed of >99% kokanee.

Control information was collected at each site prior to testing. The lights were lowered to the desired depth and the generator started, but the lights were kept turned off. The hydroacoustic boat then conducted surveys past the strobe lights to record kokanee density and distribution data. Two to five surveys were run at different angles past the strobe lights. If the strobe light boat was anchored at a single location then all of the control transects were averaged and used as a single sample. If the strobe light boat was drifting so that it moved more than 50 m between transects, then each survey transect was considered a separate sample.

Testing was conducted with the strobe lights set at 300, 360 or 450 flashes/min. Hydroacoustic surveys were then conducted past the lights in a similar fashion. The boat was then moved, or allowed to drift, to a different location and the testing was repeated with controls and test samples.

All testing was conducted at night. Attempts to test the lights during the day failed because kokanee formed tight schools during the day and were only infrequently seen on the echograms even in our control samples.

Lights were manufactured so the brightness of the flash was reduced as the flash rate increased. This was done to prolong the life expectancy of the flash heads, but it meant that two variables (flash rate and brightness) changed during our testing.

During strobe light testing, we recorded several additional variables to determine their effect on the outcome of our test. These included water clarity (measured by Secchi transparency), water depth, and date.

Tests were also conducted to see if kokanee would become habituated to the lights during the night. The boat with the strobe lights was anchored at a single location on Spirit Lake on July 30, 1997. Lights were lowered to the 12 m depth, which was the middle of the kokanee layer. Four control transects were surveyed past the lights during the first 20 minutes of the test with the lights turned off. Then the lights were turned on at a flash rate of 360 flashes/min. Over the next 5 h 50 min, 16 transects were surveyed past the lights, four at the start of flashing, two each hour during the night, and four at daybreak.

On June 18, 1997, strobe light testing was conducted on Lake Pend Oreille. Testing was conducted in water of >100 m depths to eliminate the effect of light reflecting off the lake bottom. The boat that held the strobe lights was not anchored and continually drifted during the testing. Thus, each hydroacoustic transect was at a new location and was considered a separate sample for statistical analysis. Twelve control samples, eight tests with the lights flashing at 300 flashes/min, and five tests with the lights flashing at 450 flashes/min were conducted between 2130 and 0240 hours.

Spawner Counts

We counted kokanee in four tributaries to Dworshak Reservoir to serve as a relative index of the adult population. Counts of spawning kokanee were performed in Isabella Creek, Dog Creek, Skull Creek, and Quartz Creek. We walked these streams from their mouths to the furthest upstream reaches utilized by kokanee. These tributaries were surveyed annually from 1981 to 1997 on or near September 25, the peak of kokanee spawning (Horton 1980).

Kokanee Abundance

Oblique tows of a mid-water trawl were used to obtain density estimates of kokanee and representative samples of fish for aging. An 8.5-m boat with a 140 hp diesel engine towed the trawl net that was 13.7 m long with a 3 m by 3 m mouth. Mesh sizes (stretch measure) graduated from 32 mm to 25 mm to 19 mm to 13 mm in the body of the net and terminated in a 6 mm mesh cod end.

All trawling was conducted after dark during the new moon phase to optimize capture efficiency (Bowler et al. 1979). Net towing speed was standardized at 1.5 m/s. Depth of the net was determined for each 15.2 m distance of tow cable and checked annually. The layer of kokanee distribution was determined using a Raytheon Model V860 depth sounder with a 20 degree transducer. This vertical distribution of kokanee was divided into 3.5 m sublayers; usually three to five sublayers encompassed the vertical distribution. A step-wise oblique net tow was made through the kokanee layer. The net was pulled for 3 min in each sublayer, sampling 2,832 m^3 of water over a distance of 315 m (at a boat speed of 1.5 m/s). The time it took to readjust the net between sublayers and the time the net was in the kokanee layer while initially setting the net was also entered into density estimates (approximately 30 s between sublayers while raising and lowering the net).

A stratified random sampling design was used to choose trawl locations. The reservoir was divided into three sections with Dent Bridge and Grandad Bridge serving as boundary lines (Figure 1). Section 1 was the lower end of the reservoir (2,562 ha of kokanee habitat), section 2 the middle (1,499 ha of kokanee habitat), and section 3 was the upper reservoir (520 ha of kokanee habitat). During trawling the reservoir was at 518-m elevation (1,580 ft) and the mid-point of the kokanee layer at about the 20-m depth, therefore kokanee habitat was defined as the area inside the 457 m contour (1,500 ft). Four to six trawls were made in each reservoir section. Reservoir sections were the same each year but trawl locations were randomized annually. During 1997, trawls started at rkm 5, 6, 10, 13, 24, 26, 31, 39, 48, 56, 58, 64, 66, 72, and in the Little North Fork arm at rkm 2 (Figure 1). Trawl direction was parallel to the long axis of the reservoir due to spacial limitations. Trawling was conducted on the nights of July 7, 8, and 9, 1997.

The number of kokanee of a specific age-class collected in each haul was divided by the volume of water sampled to obtain age specific density estimates. These densities were then multiplied by the thickness of the kokanee layer (in m) at the trawling site and then multiplied by 10,000 m^2 to obtain the number of kokanee per hectare at that site. Mean densities in each section were multiplied by the area of that lake section to obtain population estimates and summed to make whole-lake population estimates. Parametric statistics were then applied to the density estimates to calculate 90% confidence limits (Scheaffer et al. 1990). Mean kokanee weights in each 10 mm size group were averaged to determine the mean weight of kokanee in an age-class, and multiplied by the population estimate of that age-class to determine biomass. A detailed description of trawling methodology was presented in Rieman (1992).

RESULTS

Strobe Light Tests

The first strobe light test was conducted on May 29, 1997 in Spirit Lake. We tested the response of kokanee to a flash rate of 450 flashes/min. Secchi transparency was 3.7 m, water depth was about 22 m, and the strobe lights were 12 m deep. At each of three sites, density of fish within 30 m of the lights and the distance to the first group of fish was compared between controls (lights off) and test groups (lights flashing). In control samples, the mean distance to the fish was 7 m and the mean density of fish was 814 fish/ha (Table 1). Once lights were flashing, the distance to the first group of fish increased significantly to a mean of 39 m (P=0.036, df=2). Fish densities within 30 m of the lights dropped significantly to 138 fish/ha on average (P=0.023, df=2). Thus, fish densities were reduced 83% and fish were repelled to 39 m at the 450 flash rate in water of 3.7 m Secchi transparency.

A single sample using the 360 flashes/min rate was also tested on May 29 (Table 1). Four transects past the strobe lights showed that kokanee density dropped from 562 fish/ha to 160 fish/ha and that the distance to the first group of fish increased from 6 m to 35 m. No comparative statistics were applied to this sample since it was conducted at a single location and was considered a single sample.

Table 1. Results of strobe light testing on Spirit Lake, Idaho May 29, 1997. Each test was paired with a control sample (lights not flashing) at the same location.

Site	Flash rate	Number of transects	Distance to fish, mean of left and right (m)	Density within 30 m of lights, +/-5 m depth
1	Control	3	6	983
1	450	4	51	115
2	Control	3	8	750
2	450	4	32	236
3	Control	4	7	710
3	450	4	36	64
4	Control	4	6	562
4	360	4	35	160
± of controls (paired with 450 flash rate)			7	814
± of 450 flash rate			39[1]	138[2]

[1] Probability that increased distance to first group of fish was due to random chance; p=0.036, df= 2.
[2] Probability that decreased density was due to random chance; p=0.023, df=2.

Table 2. Results of strobe light testing on Spirit Lake, Idaho on June 17, 1997. Each test was paired with a control sample (lights not flashing) at the same location.

Site	Flash rate	Number of transects	Distance to fish, mean of left and right (m)	Density within 30 m of lights, +/-5 m depth
1	Control	4	6	1605
1	300	4	30	109
2	Control	2	8	1017
2	300	4	32	426
3	Control	2	8	979
3	300	3	27	169
4	Control	2	11	412
4	360	3	32	464
± of controls (paired with 300 flash rate)			7	1200
± of 300 flash rate			30[1]	235[2]

[1] Probability that increased distance to first group of fish was due to random chance; p=0.006, df= 2.
[2] Probability that decreased density was due to random chance; p=0.071, df=2.

Table 3. Results of strobe light testing on Spirit Lake, Idaho on July 30, 1997. Four control samples (lights not flashing) were conducted before lights were turned on with a flash rate of 360 flashes/min. All samples were collected at the same location.

Time from start of flashing lights (min)	Distance to fish, mean of left and right (m)	Density of all fish within 30 m of lights (fish/ha)	Density of fish over -48 dB (> 100 mm, fish/ha)
Control	0	1,747	1,295
Control	2	1,874	1,381
Control	4	1,200	935
Control	0	1,385	1,029
8	52	343	0
15	43	0	0
21	54	8	0
28	44	0	0
94	52	0	0
104	28	171	137
155	39	0	0
164	34	237	237
215	54	26	0
223	35	130	130
273	38	0	0
281	37	0	0
330	32	128	128
336	30	94	94
343	36	0	0
350	24	282	211
± of controls	1.5	1,552	1,160
± of test group	40 [1]	89 [2]	59

[1] Probability that increased distance to first group of fish was due to random chance; p=0.000, df= 18.
[2] Probability that the decrease in fish density was due to random chance; p=0.000, df=18.

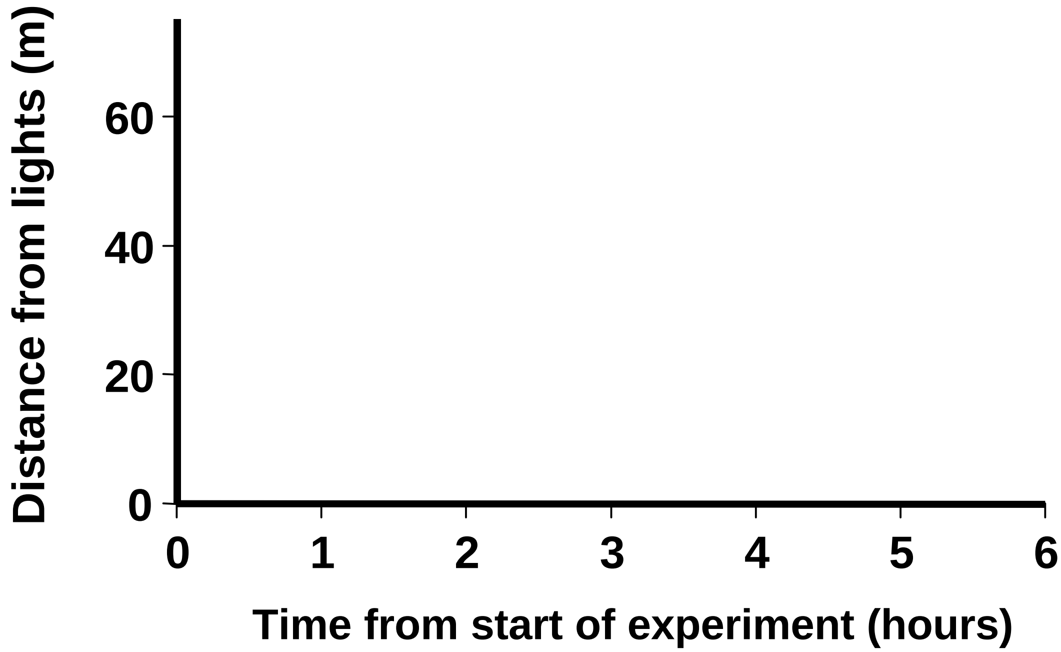


Figure 3. Distances kokanee remained away from strobe lights during a 6-hour test In Spirit Lake, Idaho on July 30, 1997.

Strobe light testing continued on June 17, 1997 in Spirit Lake. Water depth was about 20 m, and the strobe lights were placed 12 m deep. The mean density of fish was reduced from 1200 fish/ha in control samples to 235 fish/ha when the strobe lights were turned on with a flash rate of 300 flashes/min ($p=0.071$) (Table 2). This was an 80% reduction in fish densities within 30 m of the lights. Fish were repelled from the lights an average distance of 30 m which was a significant increase from the control samples ($p=0.006$).

On July 30, 1997, a test was conducted in Spirit Lake to determine if kokanee would become habituated to the strobe lights. The boat holding the lights was anchored at a single location for the entire night. In four control samples, with the lights turned off, fish averaged 1.5 m away from the lights and densities within 30 m of the lights averaged 1,552 fish/ha (Table 3). Density of fish over -48 dB (approximately 100-mm total length) was 1,160 fish/ha within 30 m of the lights in these control samples.

Horizontal distance to the first group of fish increased to 52 m once the lights began flashing. Density of all fish within 30 m of the lights dropped to 343 fish/ha and density of fish over 100 mm (-48 dB) decreased to zero fish/ha. During the 5 h 50 min of testing, there was a slight tendency for fish to move closer to the lights. However, the last three samples (5 h 36 min to 5 h 50 min) showed that kokanee remained an average of 30 m away from the lights, with fish densities of 125 fish/ha within 30 m of the lights (Table 3, Figure 3). For the entire test, fish were repelled an average of 40 m and densities within 30 m of the lights declined 94% for all fish and 95% for fish over 100 mm.

We found during our testing on Lake Pend Oreille, June 18, 1997, that kokanee remained close to the strobe lights in the control samples (lights off). Mean distance to the first group of fish was 5 m and densities within 30 m of the lights averaged 711 fish/ha (Table 4). When the lights were flashing at a rate of 300 flashes/min, the mean distance to the fish was 46 m and densities dropped to 139 fish/ha. The distance to the first group of fish was 45 m and densities were 120 fish/ha when the lights were flashing at a rate of 450 flashes/min. The probability that the change in distance and density was due to random chance was p= 0.000. Secchi transparency during this test was 2.75 m.

Spawner Counts

Only 144 kokanee were counted in the four tributaries that were surveyed (Table 5). This was a 99.6% decline from the 36,480 kokanee counted in 1995, and the lowest number recorded since counts began in 1981 (Figure 4).

Table 4. Results of strobe light testing on Lake Pend Oreille, Idaho June 18, 1997. Lights were 17 m deep over >100 m of water. Boat was drifting during experiment.

Site	Flash rate	Distance to fish, mean of left and right (m)	Density within 30 m of lights, +/-5m
1	control	0	1652
2	control	0	1234
3	300	48	95
4	300	47	0
5	control	2	424
6	control	0	629
7	300	38	206
8	300	41	66
9	control	0	732
10	control	10	189
11	450	44	229
12	control	10	665
13	control	12	644
14	300	51	190
15	300	50	0
16	control	4	628
17	control	11	974
18	450	30	211
19	450	53	126
20	control	8	145
21	control	1	620
22	450	49	0
23	450	53	128
24	300	57	307
25	300	30	92
± of controls		5	711
± of 300 flash rate		46[1]	139[2]
± of 450 flash rate		45[1]	120[2]

[1] Probability that increased distance to first group of fish was due to random chance; p=0.000, df=23.
[2] Probability that decreased density was due to random chance; p=0.000, df=23.

Table 5. Number of kokanee spawners counted in selected tributaries to Dworshak Reservoir during September 1981-1997.

Year	Isabella Creek	Skull Creek	Quartz Creek	Dog Creek	Total (Isabella, Quartz, and Skull)[1]
1997	144	0	0	0	144
1996	2,552	4	13	82	2,569
1995	12,850	20,850	2,780	1,160	36,480
1994	14,613	12,310	4,501	1,878	3,424
1993	29,171	7,574	2,476	6,780	39,221
1992	7,085	4,299	1,808	1,120	13,192
1991	4,053	1,249	693	590	5,996
1990	10,535	3,219	1,702	1,875	15,456
1989	11,830	5,185	2,970	1,720	19,985
1988	10,960	5,780	5,080	1,720	21,820
1987	3,520	1,351	1,477	700	6,348
1986	-	-	-	-	-
1985	10,000	8,000	2,000		20,000
1984	9,000	2,200	1,000		12,200
1983	2,250	135	66		2,451
1982	5,000	4,500	1,076		10,576
1981	4,000	3,220	850		8,070

[1] Total does not include Dog Creek because it was not surveyed until 1987.

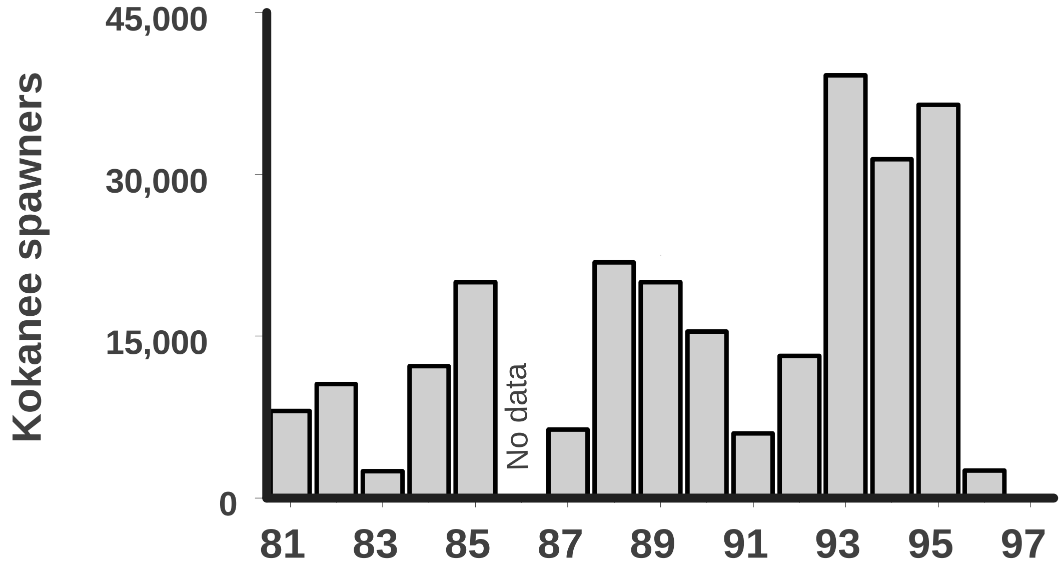


Figure 4. Counts of kokanee spawning in tributaries to Dworshak Reservoir, Idaho, 1981 to 1997.

Kokanee Abundance

We collected only eight fry during the 15 trawl hauls in 1997. No age-1 or age-2 kokanee were caught. All of the fry were caught in the lower third of the reservoir in trawls at river kilometers 5, 6, and 10. Fry ranged in size from 43 mm to 53 mm with a mean of 48 mm. Mean weight of the fry was 0.88 g. The population estimate for the reservoir was 65,000 age-0 kokanee (+/- 76%, 90% C.I.) with no age-1 or age-2 kokanee present. This was the lowest estimate of all age classes of kokanee since trawling began in 1988 (Table 6). Density of kokanee in the reservoir was 12 fish/ha with a standing stock of 0.01 kg/ha.

DISCUSSION

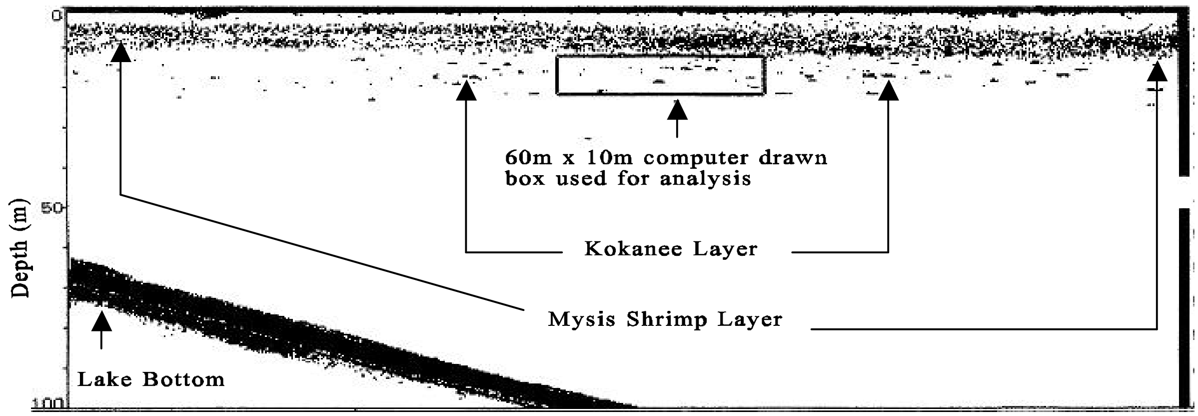
Strobe Light Tests

We found no response from kokanee during our control (lights off) sampling. The lowering of strobe lights, running the generator, movement of people on the boats, use of boat lights, and repeated hydroacoustic surveys over top of the fish did not affect the distribution or density of kokanee in the vicinity of the lights (Figure 5). Densities of fish near the lights and the densities of fish >200 m away appeared very similar, with no apparent change in density or depths.

Table 6. Estimated abundance (thousands) of kokanee in Dworshak Reservoir, Idaho, 1988-1997.

Sampling Year	Sampling Technique	Age Classes 0	1	2	3	Total	Density age-2 and 3 (fish/ha)
July 1997	Trawling	65	0	0	0	65	0
July 1996	Hydroacoustic	231	43	29	0	303	5
June 1995[2]	Hydroacoustic	1,635	1,309	595	0	3,539	110
July 1994	Hydroacoustic	156	984	304	9	1,457	69
July 1993	Trawling	453	556	148	6	1,163	33
July 1992	Trawling	1,043	254	98	0	1,043	22
July 1991	Trawling	132	208	19	6	365	5
Sept 1990[1]	Trawling	978	161	11	3	1,153	3
June 1989[2]	Trawling	148	148	175	0	471	32
July 1988	Trawling	553	501	144	12	1,210	29

[1] September trawling likely resulted in underestimation of the mature fish.
[2] June trawling likely resulted in underestimation of age-0 kokanee.



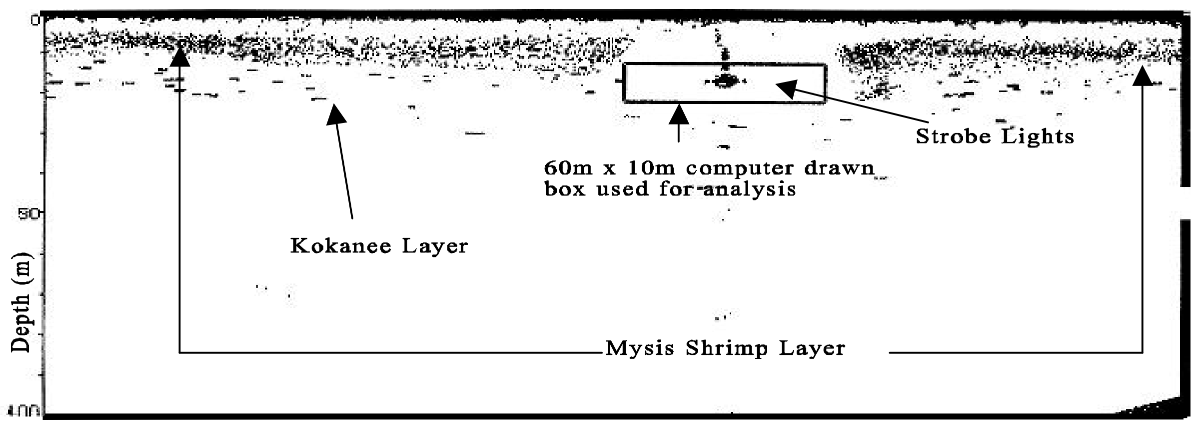


Figure 5. Echograms showing the distribution of kokanee and Mysis shrimp during strobe light tests. Strobe lights were not flashing in the top figure (control sample) and were flashing at 450 flashes/min in the lower figure.

Kokanee showed a marked change in their distribution almost immediately after the lights were turned on in each test (Figure 5). Kokanee appeared to quickly leave the area around the lights resulting in lower densities.

Kokanee responded in both deep and shallower water tests. Thus, the reflection of light off the lake bottom did not appear to trigger the avoidance response of kokanee. Little difference was seen between flash rates, however our testing was not designed to test one flash rate against another.

Very high losses of kokanee occurred from Dworshak Reservoir during the late winter and early spring of 1996 (Maiolie et al. 1998). Our hope was to find a way to minimize these losses in the future. Strobe lights appear to show promise in these preliminary tests.

Kokanee Abundance

Both trawling and spawner counts indicate the kokanee population in Dworshak Reservoir was at its lowest point on record (Table 5;Table 6; and Figure 4). Kokanee abundance is so low it is unlikely the population will rebound to densities that will provide a good fishery within the next generation of kokanee without hatchery supplementation.

CONCLUSIONS

Free-ranging kokanee showed a strong avoidance response to strobe lights in open lake environments. Testing to date would indicate strobe lights might be an effective tool in keeping kokanee away from turbine intakes. Further testing is warranted. The kokanee population in the reservoir remains at very low levels since the flooding in 1996.

RECOMMENDATIONS

1. Strobe light testing should be conducted in turbid water with Secchi transparencies less than 3 m to determine fish response.

2. If muddy water testing proves to be effective, future testing should be conducted on-site to determine the response of kokanee in flowing water under the actual conditions in front of the dam.

3. Stocking kokanee into Dworshak Reservoir for a minimum of three years appears warranted since the current population is so low.

ACKNOWLEDGMENTS

The authors would like to thank Charlie Craig and the Bonneville Power Administration for their help in funding and contracting this project. We would also like to thank David Teuscher and Tim Cochnauer for editing this report. The authors would especially like to thank Steve Elam, Eric O'Brien, and Mark Duclos for assisting with field work and strobe light testing.

LITERATURE CITED

Bowler, B., B.E. Rieman, and V.L. Ellis. 1979. Pend Oreille Lake fisheries investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-1, Boise.

Falter, C. M. 1982. Limnology of Dworshak Reservoir in a low flow year. United States Army Corps of Engineers. Walla Walla, Washington.

Horton, W. A. 1980. Dworshak Reservoir fisheries investigations. Idaho Department of Fish and Game. Job Performance Report, Prepared for United States Army Corps of Engineers, Contract Number DACW68-79-C-0034, Boise.

Horton, W. A. 1981. Dworshak Reservoir fisheries investigations. Idaho Department of Fish and Game. Prepared for United States Army Corps of Engineers, Contract Number DACW68-79-C-0034, Boise.

Maiolie, M. A., and S. Elam. 1995. Dworshak dam impacts assessment and fisheries investigations project. Idaho Department of Fish and Game, Annual Progress Report, Prepared for Bonneville Power Administration, Project number 89-99, Portland, Oregon.

Maiolie, M. A., B. Harryman, and B. Ament. 1998. Kokanee entrainment losses at Dworshak Reservoir. Idaho Department of Fish and Game, Annual Progress Report, Prepared for Bonneville Power Administration, Project number 89-99, Portland, Oregon.

Rieman, B.E. 1992. Kokanee salmon population dynamics-kokanee salmon monitoring guidelines. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-14, Subproject II, Study II, Boise.

Scheaffer , R. L., W. Mendenhall, and L. Ott. 1990. Elementary survey sampling, 4th edition. Duxbury Press, Belmont, California.

Winans, G. A., P. B. Aebersold, and R. S. Waples. 1996. Allozyme variability of *Oncorhynchus nerka* in the Pacific Northwest, with special consideration to populations of Redfish Lake, Idaho. Transactions of the American Fisheries Society 125:645-6663.

Submitted by:

Melo A. Maiolie
Principal Fisheries Research Biologist

Bill Harryman
Senior Fisheries Technician

Bill Ament
Senior Fisheries Technician

Approved by:

Virgil K. Moore, Chief
Bureau of Fisheries

Steven P. Yundt
Fisheries Research Manager